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(54) Title: IMPROVED METHOD AND ADDITIVE FOR THE VISCOSITY OF CRUDE OIL

(57) Abstract: An improved method for reducing the viscosity of crude oil is described. In particular, an improved method of reducing the viscosity of different types of crude oil over a range of temperatures is demonstrated. This viscosity reduction effect is achieved by introducing additives containing polyvinyl alcohols (PVA) to the crude oil. The resulting dispersion mixture not only shows enhanced mobility, but also facilitates the recovery of the original crude oil.

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Improved method and additive for reducing the viscosity of crude oil

The present invention relates to an improved method and additive for reducing the viscosity of crude oil and in particular to an improved method of reducing the viscosity of different types of crude oil over a range of temperatures.

Many crude oil deposits are of such high viscosity that they are very difficult to exploit without the aid of chemicals that allow the crude oil to be produced and transported to suitable locations for processing and/or shipping.

Crude oil (or crude petroleum oil) is found in nature in both surface and subsurface deposits. These deposits contain different oils which have different characteristics. For example, some crude oils contain high levels of waxes, while others contain high levels of naphthenic compounds, among many other organic components. Therefore, viscous petroleum products containing different components are extracted from

different oil fields, and the presence of high levels of these components increases the viscosity of crude oils.

When crude oil is extracted from subterranean reservoirs it is generally at a temperature which allows it to flow either naturally, or with the assistance of pumps, to the surface. In most cases, the temperature of crude oil at the surface is sufficiently high to maintain the low viscosity necessary to allow the crude oil to flow freely from the producing wells to the gathering or production system.

However, when crude oil is produced and passed through surface pipe-work, it generally loses heat. If the temperature is reduced sufficiently during this process, wax and/or other components precipitate out of the crude oil solution. Alternatively, as a consequence of the temperature reduction, the components reach such a high viscosity that the crude oil flows less readily. In fact, in many cases where viscous crude oils are produced and the temperature is lowered sufficiently, the crude oils will not flow at ambient temperatures.

Present solutions to the problem of crude oil mobility reduction involve the addition of various different chemicals which increase the mobility and flow characteristics of the crude oil. The choice of chemicals that are used is dependent on whether the precipitation or the viscosity increase mechanism is involved in reducing the mobility of the crude oil.

When the reduction in flow is caused by wax or asphaltene problems, additives such as inhibitors, pour point

reducers, or solvents may be added to increase the flow of the crude oil. These additives either change the composition of the crude oil or interfere with the mechanism of deposition. For example, solvents can change the amount of aromatic components in the crude oil solution or they can interfere with the mechanism of deposition. Whereas inhibitors can prevent precipitation of material from a specific crude oil at a specific temperature and pour point reducers can change the temperature at which crude oil stops flowing when cooled. In general, the effect of these additives is to reduce the viscosity and increase the mobility of the crude oil. However, as alluded to above, it is often necessary to choose a chemical additive that is specific to the type of crude oil and to the mechanism of mobility reduction.

In the event that specific chemicals are too expensive to use for increasing the mobility of crude oil, a generally applicable system can be used. This system involves using a surfactant and a divalent inorganic ion with a high shear apparatus to form an emulsified system referred to as Orimulsion (for which patents already exist). However, Orimulsions are water in oil emulsions (oil continuous phase) which can prove difficult to separate into oil and water. Such Orimulsions are normally used as fuel rather than being refined to produce more valuable petroleum products.

Currently, chemicals that are employed to change crude oil flow characteristics are expensive and must be used in large quantities, making the cost of using these chemicals significant. Furthermore, most of the above treatments have the drawback that they are specific to

the particular mechanism (precipitation or viscosity increase) by which the crude oil flow properties are decreased.

From the processes described above, it is apparent that present methods for reducing the viscosity and increasing the flow characteristics of crude oil suffer from several drawbacks and disadvantages.

It is an object of the present invention to obviate, or at least mitigate, some of the disadvantages associated with the prior art.

Therefore, it is an object of the present invention to provide a method for reducing the viscosity and increasing the mobility of crude oil.

It is a further object of the present invention to provide a method and additive for reducing the viscosity and increasing the mobility of crude oil which is not specific to the mechanism of viscosity increase.

A still further object of the present invention is to provide a method and additive for reducing the viscosity of crude oil which facilitates the recovery of the crude oil.

According to a first aspect of the invention, there is provided a method for reducing the viscosity of crude oil comprising the step of adding at least one additive to a crude oil, wherein the at least one additive comprises at least one polyvinyl alcohol, and wherein the resultant mixture is a dispersion mixture.

In the context of the invention, references to viscosity of crude oil should be interpreted to mean viscosity of the crude oil itself and/or viscosity of a mixture in which crude oil is present.

The method may comprise the additional step of mixing the at least one additive with the crude oil by agitation.

Preferably, the additive comprises aqueous polyvinyl alcohol.

The additive may be added by injection.

Preferably, the method is operated over the temperature range of 10° to 80°. More preferably, the method is operated over the temperature range of 10° to 40°.

The additive may be added such that it is present in the dispersion mixture in a volume range of 10 %vol/vol to 40 %vol/vol as a percentage of the dispersion mixture volume.

Preferably, the additive is added such that it is present in the dispersion mixture in a volume range of 15 %vol/vol to 30 %vol/vol as a percentage of the dispersion mixture volume.

More preferably, the additive is added such that it is present in the dispersion mixture in a volume range of 20 %vol/vol to 25 %vol/vol as a percentage of the dispersion mixture volume.

The additive may comprise a solution of aqueous polyvinyl alcohol resin with concentration in the range 0.1% to 2%. Preferably, the additive comprises a solution of aqueous polyvinyl alcohol resin with concentration of approximately 0.5%.

Preferably, the dispersion mixture comprises a continuous aqueous phase and a discontinuous non-aqueous phase.

The method may comprise the further step of adding a second additive selected to decrease the pour point of the dispersion mixture. Preferably, the second additive is a wax crystal modifier.

According to the second aspect of the invention, there is provided a method of transporting crude oil from a first location to a second location, the method comprising the steps of:

reducing the viscosity of crude oil at the first location by the method according to d in any of Claims 1 to 14;

separating the dispersion mixture at the second location.

Preferably, the dispersion mixture comprises a continuous aqueous phase and a discontinuous non-aqueous phase.

The method may comprise the further step of separating the aqueous and non-aqueous phases.

The method may comprise the step of adding a polymer breaker to the dispersion mixture.

Preferably, the polymer breaker is a periodate salt. More preferably, the polymer breaker is sodium periodate.

The method may comprise the further step of reforming the dispersion mixture from the separated aqueous and non-aqueous phases by agitating the mixture.

According to the third aspect of the invention, there is provided an additive for reducing the viscosity of crude oil, the additive comprising at least one polyvinyl alcohol and at least one wax crystal modifier.

In its fourth aspect, the invention relates to use of at least one polyvinyl alcohol as a viscosity reducing additive in a crude oil mixture.

According to the fifth aspect of the invention, there is provided a improved system for transporting crude oil from a first location to a second location, the system comprising a conduit having a crude oil mixture flowing therein, wherein the crude oil mixture is a dispersion mixture of crude oil and at least one additive and the at least one additive comprises a polyvinyl alcohol.

The method for reducing the viscosity of crude oil provides a way of increasing the mobility of crude oil in, for example, pipelines. In achieving this effect, the method produces a "water-wet" oil in water dispersion mixture. In a sense, the dispersion mixture which is formed can be visualised as waxy ball-bearings, surrounded by water.

Inside a pipeline or conduit, the crude oil forms small globules and (as described above) behaves like waxy ball-bearings inside a water sheath, and the mixture moves freely in the pipeline.

The method described in the examples uses an aqueous solution of a polyvinyl alcohol (PVA) which is generally, but not necessarily, made at high concentration and diluted. As an alternative, the polyvinyl alcohol can be produced on-site immediately before addition to the crude oil stream.

The mechanism of adding the additive is by injection into an area of mixing which does not emulsify the aqueous polyvinyl alcohol solution with the crude oil, but produces a dispersion mixture. The dispersion mixture so-formed has a continuous aqueous (or water) phase and a discontinuous non-aqueous (or oil) phase (i.e. an oil in water dispersion). This is not an emulsion, nor does it contain an emulsified phase, rather, it is a dispersion mixture.

In addition, the aqueous:non-aqueous ratios that are used in the present invention would ordinarily produce a continuous non-aqueous (or oil) phase and a discontinuous aqueous (or water) phase (i.e. a water in oil dispersion). Somewhat surprisingly, this is the opposite of the properties dispersion mixture of the present invention as described above. The dispersion mixture is therefore considered to be "water-wet", as opposed to "oil-wet". Consequently, the present invention allows the aqueous layer to be separated from the non-aqueous layer.

For each particular crude oil there is an amount of additive which preferentially can be added and which will remain dispersed, and which will not immediately drop out of solution when mixing is stopped. This additive amount is generally between 5% and 25% by volume of the mixture so-made with the specific crude oil.

The concentration of aqueous polyvinyl alcohol and the shear, or mixing force, required to form the dispersion is dependent on the particular crude oil being treated and the temperature at which the dispersion is made.

All polyvinyl alcohol materials, irrespective of saponification value, are functional in respect of crude oil viscosity reduction. Therefore, any PVA can be used to reduce the viscosity of crude oil. However, for each particular crude oil there is a PVA with a molecular weight and saponification value which is most effective. Similarly, the concentration at which the additive is effective in an aqueous solution is also crude oil specific. Furthermore, the mixing shear required to create a mixed phase system is particular for the crude oil being treated.

In certain cases, further improvements maybe made through the addition of wax crystal modifiers to the crude oil before mixing with the additive. Wax crystal modifiers interfere with crystal formation in fluids. In effect, wax crystal modifiers prevent agglomeration within oil globules and thus prevent the formation of precipitates. Therefore, depending on the type of crude oil and desired effect, wax crystal modifiers can act as cold flow

improvers, pour point depressants, viscosity reducers, paraffin deposition inhibitors, and the like. A variety of wax crystal modifiers are known in the art, and are generally identified by their function, such as cold flow improver, pour point depressant, viscosity reducer or paraffin deposition inhibitor.

For example, the dialkylalkenylsuccinates of U.S.Patent No. 2,561,232 (Rudel *et. al.*), and assigned to Standard Oil Development Company, have been known as effective pour point depressants for petroleum derived liquids since at least as early as 1951. Also, U.S. Patents Nos. 3,574,575 and 3,634,052, both of which were assigned to Mobil Corp., and the text, Chemical Additives for Fuels: Developments Since 1978, edited by M.T. Gillies (Noyes Data Corporation 1982), pages 115-152, all of which are incorporated herein by reference, disclose other types of wax crystal modifier.

Recently, polymer compositions comprising dispersions of at least one olefinically unsaturated compound and containing aliphatic side chains of at least ten carbon atoms (e.g., a polyacrylate or a polyethylene vinyl acetate related product), in a continuous liquid phase comprising at least two surfactants and a liquid polyol was disclosed anonymously in Research Disclosure (July 1995), page 501 (entry 37550), as being effective pour point depressants in crude oil (petroleum) and certain fuel oils. These too are suitable for use in combination with the method of the present invention as wax crystal modifiers.

The method of the present invention overcomes many of the drawbacks associated with the prior art and, in fact, offers several advantages. For example, a transportation system for transporting crude oil that has been treated by the method of the present invention does not require to be heated or thermally insulated keep the viscosity suitably low for the crude oil to be effectively and economically transported.

The polyvinyl alcohol additive can be rendered ineffective by the addition of a polymer breaker. For example, a polyvinyl alcohol additive dispersed in crude oil is rendered ineffective by being broken by a periodate salt either in solid form or in aqueous solution. After the addition of the polymer breaker, the disrupted polyvinyl alcohol and the water (as the aqueous phase) can be more easily separated from the crude oil (as the non-aqueous phase). The crude oil from this separation has a water content which is sufficiently low that the crude oil can be refined to generate valuable petrochemicals.

The method as described can confer sufficient stability onto the so-formed dispersion mixture to allow transportation of the crude oil. Also, the dispersion mixture is stable for short periods during which there is cessation of movement within the system.

In the event that the additive does separate from the dispersion mixture due to excess addition of chemical or prolonged cessation of movement of the crude oil mixture, the dispersion mixture can be reformed by mixing the aqueous and non-aqueous phases, even under low shear

conditions, therefore again reducing the viscosity of the crude oil mixture.

The method described involves the application of an additive which, when added to crude oil, increases the mobility, and decreases the viscosity, of the resulting mixture over a wide range of temperatures. The additive is added to the crude oil in a specific way such that a dispersion mixture, and not an emulsion, is formed. Also, the dispersion mixture formed has a continuous aqueous (or water) phase and a discontinuous non-aqueous (or oil) phase. This method of treating crude oil can be used regardless of the mechanism (precipitation or increased viscosity) by which the mobility of the crude oil is reduced.

Example embodiments of the present invention will now be described.

Example 1

A crude oil sample of southern hemisphere origin has a viscosity of less than 1000cP at temperatures above 60°C, which is close to the production temperature for the oilfield from which the crude oil sample has been taken. At this temperature the crude oil is capable of being moved by pumping systems, and is pumped along a pipeline to a suitable production separation facility.

After entering the production separation system, the crude oil cools and enters the storage system at a temperature of approximately 40°C. The viscosity of the crude oil is now between 2500cP and 5500cP. At this

temperature and viscosity, the crude oil cannot be pumped along a pipeline to the shipping point without uneconomically large pumping systems, high pressure pipelines or the provision of a fully thermally insulated, or heated, pipeline.

By the addition of various amounts of a polyvinyl alcohol solution in water (together with a system capable of dispersing, but not emulsifying, the polymer in the crude oil) the viscosity of the oil is reduced to values of 500cP or less, at temperatures of approximately 30°C.

For the particular crude oil in this example, the amount of additive required is between 20% and 25% of an aqueous solution containing 0.5% of a polyvinyl alcohol which had a viscosity of 50cP at 4% wt/wt in water and saponification degree of 86 mol% to 89 mol%.

When concentrations of less than 20% of the above 0.5% PVA solution are added, the viscosity reduction is lower, and the viscosity increases with reducing concentrations of additive over the temperature range referred to above. For concentrations higher than 25% the mixture rapidly sheds additive immediately after mixing, and the residual amount of additive dispersed in the crude oil phase stabilises at between 20% and 25%.

At the optimum concentration addition the resulting dispersion mixture of crude oil and additive is stable for up to 24 hours, and any additive that separates after this time is very easily re-dispersed by simple agitation.

Table 1 below details the viscosity and the amount of free water present in a dispersion mixture of the polyvinyl alcohol additive and the crude oil sample of the present example at a temperature of 30°C. From the table it is apparent that the viscosity drops rapidly and the percent water content rises markedly with increasing quantities of additive.

Additive (%vol/vol)	Crude (%vol/vol)	Temp (°C)	Visc (cP)	Free Water (%)
40	60	30	380	15.5
30	70	30	430	8.1
20	80	30	1080	<2.0
10	90	30	6420	<2.0

Table 1

When higher than optimum amounts of additive are added and dispersed in the crude oil, and the resulting mixture is left to stand with no agitation in cylindrical glass vessels at fixed temperature, the water phase sediments within the crude oil column such that the amount of water held in the top of the oil column is lower than that held at the bottom of the column, in addition to that separating out of the oil phase.

In this example the amount of water present, as determined by coulometric Karl Fischer titration was found to be less than 2% wt/wt at the top of the oil column. The amount of water present at the bottom of the oil column but above the interface of the oil and any separated water was over 20% wt/wt. In this test, the total additive applied was 30% and the volume of

separated aqueous phase found at the bottom of the column after 24 hours was 8%.

Example 2

Native crude oil with the viscosities as illustrated in Table 2 below (two samples from same field, different wells) contain less than 0.3% wt/wt water as determined by Coulometric Karl Fischer method.

Temperature (°C)	Viscosity (cP)	
	Sample 1	Sample 2
65	1020	553
40	3950	1760
30	12165	4820
25	33230	9820
20	82620	18130

Table 2

After dosing crude oil Sample 1 with additive at 23% (0.5% polyvinyl alcohol as previously specified above) and dispersing, the viscosities of the fluid at various temperatures are as illustrated in Table 3.

Temperature (°C)	Viscosity (cP)
40	388
30	491
25	832
20	1863

Table 3

In a further experiment, the crude oil Sample 1 containing 25% additive dispersion is placed in a beaker with a 20mm stirring bar, in an incubator at fixed temperature of 30°C, and is stirred at 120 rpm using a magnetic stirrer. This simulates the effect of movement of the crude oil in a low flow pipeline situation in which turbulent flow is not present.

The viscosity of the mixture is measured at various times as illustrated in Table 4 below. All apparatus is enclosed within the incubator to ensure that the temperature remains constant throughout the test period.

Time (hours)	Stirring Rate (rpm)	Temperature (°C)	Viscosity (cP)
0	120	30.1	513
0.5	120	30.2	503
1.0	120	30.1	537
5	120	30.1	487
8.5	120	30.2	478
16	120	30.1	551
24	120	30.1	489

Table 4

The results show that when the mixture is under constant movement the viscosity deviates little from the initial viscosity measured immediately after creation of the dispersed additive/oil mixture.

In circumstances where the crude oil and additive dispersive mixture is not constantly under movement, the

viscosity of the mixture increases as the aqueous phase sediments to the lower part of the crude oil phase.

In another experiment, the crude oil Sample 1 containing 25% additive dispersion is placed in a beaker in an incubator at fixed temperature. This is done to simulate the effect of no movement of the crude oil in a shut down pipeline situation.

The viscosity of the mixture is measured at various times. All apparatus is enclosed within the incubator to ensure temperature remains constant throughout the test period.

The water content of the top of the oil phase is determined by Karl Fischer analysis of samples withdrawn immediately before measurements for viscosity are made. The results from these analyses are illustrated in Table 5.

Time (hours)	Water Content (%) Top Oil Phase	Temperature (°C)	Viscosity (cP)	Free Water (mL) Separated)
0	25.8	30.1	528	0
0.5	23.9	30.1	583	0
1.0	22.7	30.2	650	0.2
5	15.4	30.1	1810	0.5
8.5	11.3	30.2	3620	1.3
16	4.8	30.1	7165	3.2
24	2.7	30.1	8030	4.0

Table 5

Note that the original crude oil sample, without any additive, had a water content of 0.2%, a viscosity of 12165cP, and 0mL of free water at 30.0°C. The viscosity of the mixture, however, never returns to values as high as those found in the original crude oil.

Example 3

In another experiment crude oil Sample 1 is mixed with 25% additive and agitated at 120 rpm for 24 hrs at 30°C. The viscosity is measured as illustrated in Table 6 below, before the addition of 0.1g solid sodium periodate and mixing.

Time (hours)	Temperature (°C)	Viscosity (cP)	Free Water (mL) (Separated)
0	30	536	0
0.1	Addition of 0.1% wt/wt sodium periodate		
0.5	30	1165	Trace
1.0	30	2860	3.2
2.5	30	6320	8.1
8.0	30	9170	19.5
16.0	30	10190	22.0

Table 6

After 16 hrs the top 75% of the oil column was removed and a water content by coulometric Karl Fischer determination found 3% wt/wt water present in the sample.

The polymer additive can be removed, or broken, by a polymer breaker. Also, the water content of the crude oil containing additive is reduced by the addition of the polymer breaker and with appropriate mixing.

As is widely known, the addition of a periodate salt will break 1,2, glycol head to head linkages in a polyvinyl alcohol polymeric material, where these linkages occur. This leads to the formation of lower molecular weight polymer chains which are no longer effective as a crude oil mobility enhancing additive.

When a crude oil and additive system is dispersed and the resulting mixture is treated by the addition of a sodium periodate salt at a concentration of 0.1% wt/vol, the periodate salt will reduce the polyvinyl alcohol polymer units to a lower molecular weight. The cleaved additive is then no longer able to remain as a dispersed phase and water separates quickly from the crude oil mixture.

Within a few hours, the aqueous phase sediments to the bottom of the oil column where it separates from the crude oil and can be clearly seen as a distinct, separate aqueous phase.

Example 4

In this example, tests are performed on a sample of crude oil of European origin with a pour point (the point at which the crude oil solidifies) of 23°C. This material does not respond to treatment with additive in that the crude becomes solid in both the treated and the untreated samples. Pour point measurements are made with various

concentrations of **PA082003** wax crystal modifier chemical from Baker Petrolite Limited and also in the presence and absence of 25% volume water containing various concentrations of 1 percent polyvinyl alcohol (PVA) Gohsenol GH 23 (10 % solution of aqueous polyvinyl alcohol resin) from Nippon Gohsei. The pour point is determined by allowing the oil to cool and tilting the container periodically to see if the oil flows. The results from the experiments are shown in Table 7 below. It is apparent from these results that the addition of polyvinyl alcohols markedly decreases the pour point of the crude oil when at least some wax crystal modifier is present.

Crude Oil Pour point Readings		
Concentration PA082003 Wax Crystal modifier (mg/kg)	0% PVA (°C)	1.0% PVA (°C)
0	23	23
100	20.5	15
500	20	13
1000	19	11
2000	18	5

Table 7

Example 5

In a further experiment, tests are performed on a second crude oil with a range of different crystal modifiers and polyvinyl alcohol Gohsenol GH23 (10 % solution of aqueous polyvinyl alcohol resin). The chemicals being tested are **A5603C** and **A5445** from Weatherford and **PAO 83110** and the previously tested **PAO82003** from Baker Petrolite. The crude oil is heated to the temperature of interest and

the additives are dosed at 20% of a 1% solution of polyvinyl alcohol and 2000 ppm of wax crystal modifier. The viscosity of the resultant mixture in centipoise cP is determined using a Brookfield viscometer. The results of this experiment are illustrated in Tables 8a to 8e below. From these results it is shown that the polyvinyl alcohol additive decreases the viscosity of crude oil over a range of different temperatures. It is also shown that wax crystal modifiers can help to enhance the effect of the polyvinyl alcohol additives.

Additive	**Viscosity (cP) at Temp.**		
	20°C	**30°C**	**40°C**
No add	11530	383	270
20% GH-23	3880	207	172

Table 8a

Additive	**Viscosity (cP) at Temp.**		
	20°C	**30°C**	**40°C**
A5445	1760	177	140
A5445+GH-23	363	99	39

Table 8b

Additive	**Viscosity (cP) at Temp.**		
	20°C	**30°C**	**40°C**
A5603C	5770	280	120
A5603C+GH-23	486	137	97

Table 8c

Additive	Viscosity (cP) at Temp.		
	20°C	30°C	40°C
PAO82003	5050	307	26
PAO82003+GH-23	2830	143	38

Table 8d

The present invention provides a method for reducing the viscosity and increasing the mobility of different crude oils over a variety of temperatures. Furthermore, the method of the present invention can be used regardless of the mechanism by which the crude oil has become less mobile (precipitation or viscosity increase).

The present invention also provides a method for transporting crude oil, and a method for transporting crude oil in a pipeline.

The method of the present invention overcomes many of the drawbacks associated with the prior art and, in fact, offers several advantages. In particular, the present invention does not require the use of large amounts of specific (and expensive) chemical additives for specific type of crude oil. Also, the present method operates over a wide range of useful temperatures.

Another advantage of the present invention is that the dispersion mixture which is formed is sufficiently stable to allow transportation of the crude oil, and to allow for short periods during which there is cessation of

movement within the system. Therefore, the method of transportation of the present invention does not require heating or thermal insulation for the crude oil to be effectively and economically transported.

In addition, if the additive does separate from the dispersion mixture due to excess addition of chemical or prolonged cessation of movement of the crude oil mixture, the dispersion mixture can be reformed by mixing, even under low shear conditions.

A further advantage of the present invention is that the crude oil that is recovered from the method has a water content which is sufficiently low that the crude oil can be refined to generate valuable petrochemicals.

Various modifications may be made to the invention herein described without departing from the scope thereof.

Claims

1. A method for reducing the viscosity of crude oil comprising the step of adding at least one additive to the crude oil, wherein the at least one additive comprises at least one polyvinyl alcohol, and wherein the resultant mixture is a dispersion mixture.

2. The method as claimed in claim 1 comprising the additional step of mixing the at least one additive with the crude oil by agitation.

3. The method as claimed in claim 1 or claim 2 wherein the additive comprises aqueous polyvinyl alcohol.

4. The method as claimed in any of claims 1 to 3 wherein the additive is added by injection.

5. The method as claimed in any preceding claim wherein the method is operated over the temperature range of 10° to 80°.

6. The method as claimed in any preceding claim wherein the method is operated over the temperature range of 10° to 40°.

7. The method as claimed in any preceding claim wherein the additive is added such that it is present in the dispersion mixture in a volume range of 10 %vol/vol to 40 %vol/vol as a percentage of the dispersion mixture volume.

8. The method as claimed in claim 7 wherein the additive is added such that it is present in the dispersion mixture in a volume range of 15 %vol/vol to 30 %vol/vol as a percentage of the dispersion mixture volume.

9. The method as claimed in claim 8 wherein the additive is added such that it is present in the dispersion mixture in a volume range of 20 %vol/vol to 25 %vol/vol as a percentage of the dispersion mixture volume.

10. The method as claimed in any preceding claim wherein the additive comprises a solution of aqueous polyvinyl alcohol resin with concentration in the range 0.1% to 2%.

11. The method as claimed in claim 10 wherein the additive comprises a solution of aqueous polyvinyl alcohol resin with concentration of approximately 0.5%.

12. The method as claimed in any preceding claim wherein the dispersion mixture comprises a continuous aqueous phase and a discontinuous non-aqueous phase.

13. The method as claimed in any preceding claim comprising the further step of adding a second additive selected to decrease the pour point of the dispersion mixture.

14. The method as claimed in Claim 13 wherein the second additive is a wax crystal modifier.

15. A method of transporting crude oil from a first location to a second location, the method comprising the steps of:
    - reducing the viscosity of crude oil at the first location by the method according to d in any of Claims 1 to 14;
    - separating the dispersion mixture at the second location.

16. The method as claimed in claim 15 wherein the dispersion mixture comprises a continuous aqueous phase and a discontinuous non-aqueous phase.

17. The method as claimed in claim 16 comprising the further step of separating the aqueous and non-aqueous phases.

18. The method as claimed in any of claims 15 to 17 including the step of adding a polymer breaker to the dispersion mixture.

19. The method as claimed in claim 18 wherein the polymer breaker is a periodate salt.

20. The method as claimed in claim 19 wherein the polymer breaker is sodium periodate.

21. A method as claimed in Claim 1 to 14 wherein the method comprises the further step of reforming the

dispersion mixture from the separated aqueous and non-aqueous phases by agitating the mixture.

22. An additive for reducing the viscosity of crude oil, the additive comprising at least one polyvinyl alcohol and at least one wax crystal modifier.

23. Use of at least one polyvinyl alcohol as a viscosity reducing additive in a crude oil mixture.

24. An improved system for transporting crude oil from a first location to a second location, the system comprising a conduit having a crude oil mixture flowing therein, wherein the crude oil mixture is a dispersion mixture of crude oil and at least one additive and the at least one additive comprises a polyvinyl alcohol.

INTERNATIONAL SEARCH REPORT

Inte nal Application No
PCT/GB2005/001424

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C10M145/04 C10L1/18 C09K3/00 F17D1/17

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C10M C10L C09K F17D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 641 433 A (CHIRINOS ET AL) 24 June 1997 (1997-06-24)	1-3, 5-10, 12-17, 21-24
Y	column 2, line 35 - column 3, line 15 column 3, line 50 - line 64 claims	18,19
X	US 3 542 044 A (GERALD D. HANSEN ET AL) 24 November 1970 (1970-11-24) column 1, line 52 - line 66 column 5, line 20 - line 35 claims; table 5	22

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 July 2005	05/09/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Dötterl, E

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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X	GB 1 304 002 A (SHELL INTERNATIONALE RESEARCH MATSCHAPPIJ N.V.) 24 January 1973 (1973-01-24) page 1, line 61 - page 2, line 85 claims; examples	24
X	GB 2 317 895 A (* BRADFORD UNIVERSITY) 8 April 1998 (1998-04-08) page 6, line 21 - page 9, line 15 claims; examples	22
Y	page 18, line 20 - line 26	18,19
A	US 6 178 980 B1 (STORM DAVID A) 30 January 2001 (2001-01-30) the whole document	1-24
E	WO 2005/040669 A (ADVANCED GEL TECHNOLOGY LIMITED; FLETCHER, PHILIP; CRABTREE, MICHAEL,) 6 May 2005 (2005-05-06) the whole document	1-24

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Information on patent family members

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